AD-A139 447 EXPERIMENTS TO CORRECT A DIGITAL MAP DATA BASE USING SCENE ANALYSIS(U) INSTITUTE FOR IMAGE PROCESSING COMPUTER MAPPING GRAZ (AUSTRIA) F LEBERL MAR 84 1/1

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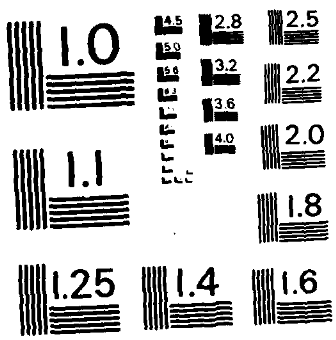
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AD A139447

EXPERIMENTS TO CORRECT A DIGITAL MAP DATA BASE USING SCENE ANALYSIS

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Contract Number DAJA 45-83-C-0022

Contractor

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Fourth Progress Report
Covering the contract period from
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Concepts and methods used in correcting a digital map base with scene analysis are presented in summary form.

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1. Scientific Work Done During The Reporting Period

(a) An overview of the concepts developed during the first year of this project, which we name now for short "Photo-Interpretation Expert" PHIX is attached to this report. It contains also a listing of functions of the image processing system DIBAG.

(b) The aerial image material is partly digitized and is available on digital tapes. Preprocessing which compensates for errors due to the scanning process was carried out.

(c) The test of the interface to DESBOD, the map data base and geoinformation system, proved successful so that realistic map data will now be entered.

(d) Experiments for feature extraction for monochrome images, including texture and neighbourhood-related properties, are carried out to select optimal data for object recognition.

(e) The image-to-image registration procedure was extended by a module where ancillary navigation data may be used to generate the anchor point grid for resampling. Geometries may be those of metric cameras (central perspective) or spectral scalling systems. The module includes access to a digital terrain model so that also images of areas with more complicated topography may be considered.

2. Research plans

During the third quarter in the project's schedule the following tasks will be treated:

(a) Test of recognition procedures and segmentation with map data.

(b) Investigations of possibilities to describe general knowledge in the relational data base level of the geoinformation system.

(c) development of raster-to-vector-conversion algorithms for the symbolic description of located objects.

3. Significant Adminstrative Action

None.

4. Other Information

H. Ranzinger presented a paper "Map-Guided Feature Detection in Aerial and Satellite Images" at the Workshop "Pattern Recognition in Photogrammetry" held in Graz, Austria, September 27-29,1983. A paper "A Geoinformation Expert System for Synergetic Use of Map and Image Data" and a poster paper "Combinations of Remote Sensing Data with a Digital Map Data Base", by H. Ranzinger and M. Ranzinger, will be presented at the EARSeL Eighth General Assembly and Symposium to be held at Guildford, England, April 8-11,1984. They will appear in the proceedings and will be submitted to ERO at the appropriate time.

5. Financial Statement

ERO-Support only

Amount received		USS 16 500.-
Personnel (one year)	USS 21 000.-	
Other expenses	USS 1 000.-	
Amount spent	USS 22 000.-	

6. Important Reports Acquired

None.

Graz, 31 December 1983

Prof. Dr. F. Leberl

Attachment to Fourth Progress Report
Contract Number DAJA 45-83-C-0022

Correcting a Digital Map Data Base by Scene Analysis: Concepts and Methods

H.Ranzinger F.Leberl

Graz Research Center

Introduction

The field of applications of computer sciences is rapidly increasing. At the beginning, computers were used in the original sense of the word, namely to calculate numerical problems. Soon the question arose whether these machines were capable of performing "intelligent" tasks which go far beyond purely mechanical procedures. This lead to the emergence of a new branch in science: Artificial Intelligence (AI).

The goal of artificial intelligence is to propose and develop methods which make use of a computer's capabilities to process information similar to biological organisms. Here, one of the information sources is visual perception, with which computer vision in concerned. Computer vision is, after Ballard and Brown (1982), the "construction of explicit, meaningful descriptions of physical objects from images".

Modern imaging systems acquire image-like representations of the world already in digital form. Much effort has been put into information extraction from these data alone and has yielded a solid basis of digital image processing methods. However, human perception of the world involves knowledge, which is mostly acquired by learning and subsequent deduction. The issue in artificial intelligence is therefore to make knowledge in some form also accessible to automata.

Expert Systems And Knowledge

The incorporation of knowledge in a program leads to so-called expert systems. Nau (1983) gives an overview of the concepts involved. The model for problem-solving is stated explicitly in a knowledge-base. This may be termed as propositional or descriptive representation as opposed to procedural knowledge where the program code itself contains the strategies to be taken.

McCalla and Cercone (1983) name the following approaches to knowledge representation

- semantic networks
- first-order-logic
- frames
- production systems

The knowledge-base is manipulated by a separate control strategy. Of course, on a high level, the control structure itself, as it is a program, incorporates again procedural knowledge, namely how to handle the knowledge-base, and thus limits the set of actions which can be made. Thus, today's expert systems are constructed with respect to particular applications, at present predominantly in medical consulting and in natural language understanding.

Specification Of The Problem Of This Study

In this study, we ~~are~~ concerned with one special aspect of the computer vision: How can knowledge in the form of a digital map serve in automatic image interpretation, and, on the other hand, how can interpretation results be used to change or update the map? In a wider sense, "map" may mean any graphic representation of a scene that is imaged. Here, in particular, ~~we~~ deal with maps in the cartographic sense, and with images from airborne photographic systems. One of the obvious applications is the correction or densification of a map data base using time series of aerial surveying imagery.

The aim of this study therefore is the design of a strategy to evaluate the usefulness of image-map correspondence to aid the interpretation of digital aerial photography. This is the first step to be taken towards a photo-interpretation expert system, which we shall henceforth name PHIX.

Aerial photography is one source for the update of cartography. It is acquired on a regular basis, however, the updating for many map series is, as a rule, several years. Support in the interpretation of the imagery can be given by focussing on changes rather than on invariant information. Thus the attention of the human interpreter can be directed to relevant locations in an image and, in a next step, supplying hypotheses about the nature of the inconsistencies between map and image. He then can interactively work on the data indicated and enter his interpretation in a suitable form.

A Review Of Literature

Several efforts have been described in the literature to use a map data base to analyse aerial images.

At the Stanford Research Institute, Barrow et al. (1977), Tenenbaum et al. (1978) or Fischler et al. (1979) used map data to guide feature detection. Roads or coastlines were identified by predicting their locations and thus restricting the search in the image matrix to small areas where elaborate pattern recognition methods could be applied.

Lantz et al. (1978) describe an approach taken at the University of Rochester. A semantic network is used to represent declarative and relational knowledge of the image contents. The nodes in the network describe which procedures are to be performed during interpretation.

At Carnegie-Mellon University, McKeown (1982) and McKeown and Denlinger (1982) report on a semi-automatic image understanding system which relies on a pictorial database, a map data base and a rule base, where the rules have general knowledge about objects of the real world rather than present particular facts about specific objects. A first application - the segmentation of airport scenes - shows the feasibility of this approach, though the very general concept pays - at the current state of available computing power - a heavy computing time penalty.

Havens and Mackworth (1983) from the University of British Columbia describe the Mapsee2-system which uses schema models in a network. Each model represents a class of objects, providing a description of the generic properties of every member of the class and specifying possible relationships of the class with other schemata in the network. With this knowledge, a structural description of the map is provided which guides the segmentation process on an aerial image.

The German Research Institute for Information Processing and Pattern Recognition (FIM) exhibits activities reported by Sties et al. (1977) or Kestner (1980).

Previous Own Work

The project is based on previous work performed under ERO Contracts and ongoing efforts in the development of geoinformation systems. Kropatsch and Leberl (1981) developed a first concept of a relational digital map data base and showed its applicability in map-guided control data acquisition for digital satellite image rectification. Leberl and Ranzinger (1982) extended the idea of map-image-correspondence to aerial digital photography. In both approaches, recognition procedures were implemented to identify objects in the imagery with the help of templates taken from the map data base. The basic image processing algorithms were implemented on a dedicated device (digital video processor). A comprehensive set of primitive image operations was defined which can be, by means of an interpreting program, combined to perform more complex procedures (Ranzinger, 1983). The idea of the first map data base is currently being extended to develop a geoinformation system (Kainz and Ranzinger, 1983).

Layers Of A Computer Vision System

Problem solving in artificial intelligence involves a multiple-layer structure from the top, where a problem is stated, to the bottom, where circuitry in the computer carries out a sequence of primitive operations fixed by the processor(s) incorporated. Figure 1 gives an idea of this layer structure, where upper layers control lower layers and lower layers serve as tools for operations intended by upper layers. This schematic representation is, of course, not complete, but can be detailed at various levels of

complexity.

Basically, top-down concepts or bottom-up-concepts can be constructed. However, top and bottom are ill-defined entities. At each complexity level it may be valid to assume all lower layers to be "black boxes" with an interface only existing to the layer immediately below.

In the problem under consideration, we define the layers "scene analysis" and "map data manipulation" as the bottom and eventually will work upwards keeping in mind that an expert system in computer vision is the fir goal. Thus we have to verify that we can make use of too provided by previous investigations.

Tools In Image Processing

The image processing system currently in use is DIBAG, supporting research rather than being a production tool. It incorporates actually two more or less equivalent subsets. One subset is designed to work on general-purpose hardware and therefore is basically portable from one computer architecture to another one. The second subset makes use of

PROBLEM DEFINITION
INFORMATION AND DATA DEFINITION
DATA AND KNOWLEDGE REPRESENTATION AND STRUCTURES
SYMBOLIC DESCRIPTION EXTRACTION
SCENE ANALYSIS MAP DATA MANIPULATION
IMAGE PROCESSING - MAP DATA PROCESSING
IMAGE OPERATORS - GRAPHICS OPERATORS
PRIMITIVE FUNCTIONS
COMPUTER LANGUAGES
DEVICE INTERFACES
HARDWARE / FIRMWARE

Figure 1: Layers of a computer vision system for the exploitation of map - image correspondence

an interactive image processing workstation and is thus hardware-dependent. However, an image processing language has been defined which allows problem-oriented algorithm formulation. Details on the functions of each of DIBAG's components are given in the appendix.

Special applications are implemented at first outside the system itself, but using the conventions regarding data handling. A subroutine library is available which incorporates the basic functions for image access and user interface. Generally applicable algorithms are finally taken over and become standard.

In this study, recognition procedures are of special interest. The original stock of histogram analysis, relaxation and correlation has been extended by a line follower based on gradient magnitude, simualtaneous region growing under restrictions and statistical feature-space classification. Sequences of procedures are bound together to yield new functions by writing "macro"-operations in the control language of the computer system.

Tools In Map Data Processing

Based on the experiences gained from a previously used map data base (Leberl and Kropatsch, 1980) the geoinformation system DESBOD is currently under development.

The system comprises three principal parts: A data compilation system to digitize spatial data and to assign attributes, a map data base system for management and retrieval, and a data analysis and output system. It is primarily intended to be use for environment - related planning and monitoring and for geoscientific research.

The data structures involved are

- graphic elements and
- thematic elements.

Graphic elements are points, lines and regions which are consist of the graphic primitives "edge" and "node". The graphic elements are on the one hand coordinate-related to represent their spatial locations and on the other hand related to one another by their topologic properties such as adjacency or inclusion.

Thematic elements are assigned to the graphic elements thus giving further descriptions of properties of the real-world-objects represented in the data base. Again, relations exist between thematic and graphic elements as well as among thematic elements themselves.

For flexible and quick retrieval, most of the relations are stored explicitly so that various data access paths can be selected. Through this construction, it will be possible to extend the system to a general knowledge-base by adding an additional layer which describes, on an abstract level, interrelations and inferences of thematic elements in the sense of a world-model. However, this ambitious extension will involve further research beyond the scope of this study.

The data analysis system as well as the cartographic output system are, at present, of no concern for this work, and will therefore not be described here.

Connections Between Image Processing And Map Data Processing

The data structures for images and for maps differ because of their acquisition philosophy and the operations intended on them.

Images are stored as matrices and contain at first no explicit information on a structural level, whereas spatial data of maps have the form of vectors associated with location coordinate and can therefore be from the beginning labelled with relational properties. Images are formed "physically" by discretizing a signal which varies over a two-dimensional domain, treating each point uniformly; map data are digitized "logically" by entering meaningful entities such as lines or boundaries from which the objects can easily be reconstructed.

To use map data in image processing and to incorporate scene analysis results to update map information, these structures have to be adapted to one another (Figure 2).

The procedure of vector-to-raster-conversion is well-known and has been used in previous investigations. Single objects can be retrieved from the map data base and transformed to templates or masks. A more involved procedure has to be applied when a whole raster frame must be filled with labels for different regions which together cover the entire area. Most algorithms have difficulties to preserve geometric properties such as area and adjacency under discrete metrics, especially for small objects. Figure 3 indicates the problem by a simple example.

Raster-to-vector-conversion is, for single objects, also relatively easy to handle. However, the errors occuring during processing (discretisation and curve fitting) do not allow conversions to be strictly reversible.

```
                      VECTOR-TO-RASTER-CONVERSION

---------------------                 ------------------------
I                   I   --------->    I                      I
I MAP DATA STRUCTURE I                I IMAGE DATA STRUCTURE I
I      VECTORS      I                 I     IMAGE MATRIX     I
I     RELATIONS     I                 I   RASTER OF PIXELS   I
I                   I   <---------    I                      I
---------------------                 ------------------------

                      RASTER-TO-VECTOR-CONVERSION
```

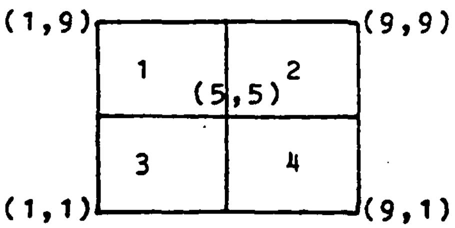
Figure 2: Adaption of map and image data structures

When transforming entire frames to the vector structure an additional problem arises. As the conversion goes from a data structure with low-level implicit relations to high-level explicit relations, these have to be reconstructed. This means that not simply boundaries are of interest, but rather the edges and nodes which separate the different objects. This holds not only for the integration of analysis results into a particular data base, but also if we try to get symbolic descriptions of the image contents.

Approaches To Scene Analysis

Change detection in imagery can be approached in different ways depending on the level of data abstraction.

The most simple process involves only the image domain. Two images have first to be registered with respect to their geometries. Leberl and Ranzinger (1982) have shown that modern instrumentation for navigation can give very accurate ancillary data with which a preliminary registration can be accomplished. A fine overlay with sub-pixel accuracy is possible by subsequent digital correlation. Image differencing then yields indicators for changes. The advantage of this method is mainly its easy implementation. A rough sketch of image contents is thus possible. However, it does not take into account different light conditions and does not yield any clues as to what has actually occured. As a preprocessing step, it may prove nevertheless valuable.



vectors and coordinates

1	1	1	1	2	2	2	2	2
1	1	1	1	2	2	2	2	2
1	1	1	1	2	2	2	2	2
1	1	1	1	2	2	2	2	2
1	1	1	1	2	2	2	2	2
3	3	3	3	4	4	4	4	4
3	3	3	3	4	4	4	4	4
3	3	3	3	4	4	4	4	4
3	3	3	3	4	4	4	4	4

resulting raster

Figure 3: Difficulties in vector-to-raster conversion. Four congruent squares in vector representation do not yield congruent squares in the raster

A complex approach takes place on the symbolic level. Here, the image is first segmented into meaningful parts. These parts are then described in a relational structure which also contains shape and grey value properties. These parts are then matched with the symbolic description of the knowledge-base, in this case with the map contents. In many cases where no detailed spatial knowledge is available, the method proves to be feasible. The segmentation process uses only image-inherent information and will thus be rather complicated. But there exists in our context a comprehensive description of what is to be expected in the image which can be used to guide segmentation.

This leads to a third approach which we are taking in this study: The map data base contains positional as well as relational information to make meaningful segmentation possible. The correspondence between map and image which can first coarsely be established by recognition procedures (developed in previous investigations) is stepwise refined by matching objects of the map data base to image features. The segmentation processes can be made considerably complex without becoming untolerably time-consuming, as the areas in the image domain that qualify for inspection are small. The topological relations represented in the map data base can be exploited to make the search for objects goal-oriented. The spatial description can be exploited to verify recognition by comparing the results obtained to the results expected. Non- verification may point out areas which have undergone changes.

A Strategy

The strategy to be taken relies on the tools provided.

(a) establish geometric correspondence between map and image

(b) select object from data base

(c) transform object to image data structure

(d) select suitable recognition procedure

(e) recognize object

(f) verify match

(g) if verification successful, mark object as present and continue with (b)

(h) if not verified, mark area as unidentified and continue with (b)

This strategy is terminated if the data base is exhausted or a large number of mismatches indicates a severe error. Result is a list with matched/unmatched object and an image which shows the segmentation results. The interpreter now may enter an interaction with the system to resolve identification problems. Updates are optionally entered to the map data base.

Test Data

The aerial imagery selected for test purposes consists of a multitemporal series of four overflights which cover a period from June, 1968 to May, 1982. Scales range from 1:9000 to 1:30000, thus representing different degrees of detail. The imaged area lies south of Graz and was also used in previous studies. There is no significant terrain relief so that problems with geometry should be minimal.

The photos document urban growth with new infrastructure (motorway), industrial settlements and suburban housing. The river Mur serves as an invariant backbone as well as some mayor roads in the area. Agricultural land use and forest are other dominant components. Thus, various tests can be carried out on features with different characteristics.

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D I B A G - Instruction Set

Note : Instruction marked with an asterisk (*) require special hardware devices; instructions marked with a plus (+) sign are computer installation dependent

Read/write of Magnetic Tapes with Various Formats
Data Reformatting

CT256		computed tomography
DEZDSK		read list with decimal grey values
LDSAT		LANDSAT MSS - NASA
OPTIN		read Optronics - scanner image data
OPTOUT		write image data for output on Optronics filmwriter
SAR		SAR-580 (airborne radar)
SARTEST		ancillary information SAR-580
SEASAT		SEASAT JPL - format
TELSAT		LANDSAT MSS Telespazio - format
TELEHD		ancillary information LANDSAT - Telespazio - format
TELRBV		LANDSAT RBV Telespazio - format

Image Rendition

BDDEZ		print image grey values as decimal data matrix
BDGRAY	*	image hardcopy on electrostatic plotter
PLOTFO	*	plot contour lines
PRINT		print image on lineprinter with 8 grey levels and automatic histogram equalisation

Image Manipulation

CHEOPS		image pyramid generation
COPYBD		copy (sub)image considering optionally given lookup-table and binary mask
DIRECT		geometric transformation (magnification, reduction, rotation)
GRKEIL		insert grey value reference scale into image
LADBGR		create image file with constant pixel value
NOISE		impose synthetic noise onto image

Image Statistics

GENHIS		generate histogram and store on work-file
HIST2		generate two-dimensional histogram and store as image
LIHIS		read histogram from image file to work-file
MINMAXBD		compute minimum and maximum value in image
PLOHIS	*	plot histogram
PRIHIS		print histogram
SPAHIS		column histogram of binary image
STOHIS		store histogram in image file
ZEIHIS		line histogram of binary image

Vector-to-Raster-Conversion

POLBIN		rastering of polygon given by vectors, result is binary image, optionally with polygon fill
POLFIT		smoothe polygons
POLGEN		generate polygon file from level contours
POLINF		print polygon file information
POLPLO	*	plot polygons

Geometric Rectification

GRIGEN		compute deformation description grid from control point data with polynomial warp functions
GRIANA		control print of grid data
PLOKNO	*	control plot of grid data
RESAMP		image resampling
CORREL	*	digital image correlation

Digital Terrain Model (GTM) Processing

BDGTM		convert DIBAG-image to GTM-format
GTMBD		convert GTM-format to DIBAG-image
OBERFL		generate surface file for perspective view rendition
D3DISP	*	synthetic perspective view of terrain data with different illumination models optionally generation of distortion information
PQPARA		compute local normal vectors
SLOPE		compute slope and exposition of surface points
VISBIN		generate mask with visibility information
ILLUIM		generate image with synthetic illumination

Interface to DeAnza image display and image array processor

ANZABD	*	read image from display memory and store in DIBAG-Format on disk
ANZLOK	*	read lookup-table from table memory and store in DIBAG-work-file
ANZMAS	*	read binary image from graphics memory and store in DIBAG-work-file
BDANZA	*	display subimage on monitor (8 bit quantisation)
DISPLAY	*	display subimage on monitor (16 bit quantisation)
LOKANZ	*	transfer lookup-table from DIBAG-work-file to table-memory
MASANZ	*	transfer binary image from DIBAG-work-file to graphics memory

D I B A G - Instruction Set

Note : Instruction marked with an asterisk (*) require special hardware devices; instructions marked with a plus (+) sign are computer installation dependent

Read/write of Magnetic Tapes with Various Formats
Data Reformatting

CT256		computed tomography
DEZDSK		read list with decimal grey values
LDSAT		LANDSAT MSS - NASA
OPTIN		read Optronics - scanner image data
OPTOUT		write image data for output on Optronics filmwriter
SAR		SAR-580 (airborne radar)
SARTEST		ancillary information SAR-580
SEASAT		SEASAT JPL - format
TELSAT		LANDSAT MSS Telespazio - format
TELEHD		ancillary information LANDSAT - Telespazio - format
TELRBV		LANDSAT RBV Telespazio - format

Image Rendition

BDDEZ		print image grey values as decimal data matrix
BDGRAY	*	image hardcopy on electrostatic plotter
PLOTFO	*	plot contour lines
PRINT		print image on lineprinter with 8 grey levels and automatic histogram equalisation

Image Manipulation

CHEOPS		image pyramid generation
COPYBD		copy (sub)image considering optionally given lookup-table and binary mask
DIRECT		geometric transformation (magnification, reduction, rotation)
GRKEIL		insert grey value reference scale into image
LADBGR		create image file with constant pixel value
NOISE		impose synthetic noise onto image

Image Statistics

GENHIS		generate histogram and store on work-file
HIST2		generate two-dimensional histogram and store as image
LIHIS		read histogram from image file to work-file
MINMAXBD		compute minimum and maximum value in image
PLOHIS	*	plot histogram
PRIHIS		print histogram
SPAHIS		column histogram of binary image
STOHIS		store histogram in image file
ZEIHIS		line histogram of binary image

Gray Scale Modification (Lookup-Tables)

HISLOK	generate table for equalisation according to given distribution function
LOK	manipulate lookup-table
NEGATE	invert lookup-table
SETLOK	set linear table

Spatial Filters

LAPABS	Laplace - absolute value sum
LAPLAC	Laplace
LAPPOS	Laplace - absolute value
MASK33	general 3x3 - filter with user-defined weights
RANGOP	rank operator (e.g. median, minimum, maximum)
ROBABS	Roberts - absolute value
ROBERT	Roberts
ROBMAX	Roberts - maximum
SMOOTH	averaging
SOBABS	Sobel - absolute value
SOBEL	Sobel
SOBMAX	Sobel - maximum

Image Combinations

ADIMAG	linear combination f(G,H) = a.G +/- b.H
DIST	distance image (values represent distances from mask)
RATIO	ratio image
THRESHOLD	image thresholding
VECLEN	vector length image

Processing of Binary Images and Masks

BINAREA	compute area and centre of gravity
BINCORR	correlate masks
BINDRU	print mask
BINEX	disable processing of mask
BINFIL	fill interior of area given by mask
BININ	enable processing of mask
BINOP	logical combinations of masks
BINSHI	shift mask within its window
LIBIN	load mask from image file to work-file
LIMAS	load mask from mask file to work-file
MASKBD	set image pixels to constant value at locations defined by mask (choropleth generation)
NOTBIN	complement of mask
REGION	region growing
STOBIN	store mask from work-file on image file
STOMAS	store mask from work-file to mask file

Line Following

PASCOO	interactive input of line transition points
LINSEA	line following - forward search
TRACK	line following - backward search

Organisation

ASN	+	assignment of input/output devices
BDINFO	+	information about existing images
BKW	+	definition of actual image name and window for subsequent processing steps
COM	+	insert comments into work protocol
END	+	end of DIBAG session
EXIT	+	pause in DIBAG session
HELP	+	information about instruction set
KILLBD	+	delete image file
KILLBIN	+	delete mask work-file
KILLHIS	+	delete histogram work-file
KILLLOK	+	delete lookup-table work-file
KILLWORK	+	delete all work files
LOG	+	print work protocol
WORK		information about work-file contents

```
!
!               DEANZA TASKS DESCRIPTION         on 25-OCT-83 ÄPOWÜ
!
!              Directory ÄDEANZA.FZG.EXEÜ                  Programs
!

================   Image Transfer    =================================

SAVPIC          save image memories to disc file
SHOPIC          get image from disc file
SHO256          display four different images in 256**2 windows
-
================   Image Processing   ================================

ADATHR          adaptive thresholding
ARUTIL          perform arithmetic operations on channels
AUTCOR          autocorrelation function via DEANZA
AUTOCR          autocorrelation under a 256x256 (max) cursor rectangle
AVERAG          mean of four images
BASRLF          biased simple edge operator
CONVLV          convolution with cos-exp or own mask
DIDXY           simple edge operator
DIFVEC          difference vector image from max.5 images
DIST            mask distance transform
DVP             DVP program interpreter
EDGE            various edge enhancement techniques
LAPLAC          Laplace edge operator
MEDIAN          median approximation under 3x3 mask
MINMAX          minimum and maximum  under nxn mask
NDTEST          normal distribution test; CHI square
PCT             principal component transformation - compute
PCT1            principal component transformation - transform
RATIO           ratio image
REGAVG          regional averige for texture parameter acquisition
ROBERT          Roberts edge operator
SETPCL          assignment of selected colours to arbitrary pixelvalues
SHOCLA          show pixels with cursor defined values in two images
SOBEL           Sobel edge operator
THRESH          interactive threshold determination
VECLEN          create vector length image
-
================   Binary Image Processing   ========================

BINRNK          rank operator on binary image
BLOSHR          blow/shrink rank operator
MASKCL          clean binary mask
MASKOP          set/clear pixels in binary mask according to neighbors
MASKWD          calculate DIBAG window of binary mask
PCTBIN          PC-trafo for masks
SHOBIT          show binary image transformation table
SKELET          skeletonisation
-
================   Memory Manipulation    ===========================

CLRMEM          clear memory
CPYMEM          copy memories
FLICKR          exchange two image channels
FLIP            mirror or rotate image channel
SPLIT           copy half image
-
!
```

================ Image Enhancement ============================

ENHAN	image enhancement via LUT; lin.ramp from 0.1-99.9%
ENHANC	image enhancement via LUT; lin.ramp from 1-99%
EQUAL	automatic linear ramp generation
HILITE	blinking threshold region
IHSRGB	intensity-saturation-hue to RGB
IHSRGBHR	intensity-saturation-hue to RGB; high resolution
IP5MCC	contour lines
IP5UNI	histogram equalisation
JP5ITT	manipulate lookup-tables with joystick
MANITT	special functions for rendition on screen
PLOTIT	plot ITTs in G/O
PSEUDO	interactive pseudo coloring module
REDRES	change image resolution
SETITT	manipulate ITTs or LUTs
SFG	set SFG parameters
SPLICU	manipulate splitscreen coordinates with joystick
WIND16	manipulate ITTs for 16 bit image data

================ Histograms and Statistics ========================

HISTO	calculate print and plot a histogram
HIST2	two dimensional histogram
LINHIS	generate line histograms
PIXVAL	interactive pixel value determination
ROBUST	robust statistic estimates from image
SNSHIS	separate histograms for each Landsat sensor
THRLIM	calculate limit under which p percent of pixels lie

================ Zoom and Scroll ===============================

INTPZM	zoom with software interpolation
JSCRZM	scroll and zoom image
JSCZM1	scroll and zoom image 1024*1024
JSELZM	zoom image
LDSCR	scroll three images simultaneously in SFG windows
SMALL	reduce 512x512 image to 256x256 in upper left quarter

================ Graphic Overlay ================================

PLTMAP	superpose map (vector) data
REGDEF	define region with joystick and vector fill
SETIT4	manipulate ITT for graphic overlay
SETOV	set pixels in G/O with joystick
TICKS	plot tick grid or various marks

================ Image Annotation ================================

EDITAN	edit annotation overlay
IP5ANW	write annotation
SHOWAN	get annotation from disc file
SHOWPG	load the A/O from a text file
SAVEAN	save annotation to disc file

Miscellaneous

ANZDEZ	print image window values defined by cursors
BWLOOP	loop through black/white rendition of channels
GENPIC	generate .PIC file with 0-values
IMLOOP	show animated 'film'
SELCP	select control points
SKALA	show scale marks on reference scales
WRSCAL	write reference scale to image file or channel

Classification

ANACLA	analyze classification statistics; print value ranges of gray values for each image
ANAHIS	analyze histogram to show multiple classifications
BILANZ	count classified pixels in selected raster
BILGRA	result of BILANZ as image
CLADIS	compute class.distances per image on .STA file
CLUSTA	cov.matrix,inverse and determinant; corr-matrix; eigenvectors of the cov-mat.for a set of train-pixels
CMPCLA	comparison of classification results
JMDIST	distances of clusters
MAXCLA	reclassify image according to most frequent class in the neighbourhood of each pixel
MAXLIK	maximum likelihood classification
MINDIS	minimum distance classification
PAREPI	parallel epiped classification
PIXLST	list of pixel coordinates which are marked in G/O
PIXSTA	compile statistics for training areas
PLTFEA	plot of feature vectors
PLTMAP	draw situation over img
PXVLST	get feature values for pixels in training areas
RECLAS	reclassify multiply classified pixels
SCATTER	scatter plot of training pixels
SHOCLU	interactive classification
TESTMD	a priori test minimum distance classification
TESTML	a priori test max.likelihood classification
TESTPE	a priori test parallel epiped classification

Versatec Interface

ANZBIN	output of binary mask of G/O to VERSATEC or .BIN file
ANZCOL	output of image with gray scale software to VERSATEC
ANZCOLF	output of image with gray scale software to .BIN file
BINOUTPRI	genererate plotfile for PRISM dot matrix printer

Test and Demonstration

CNVRGE	test image
COLTAB	color table for color selection
DEMBOX	demonstrate rextangle generation
DEMCUR	demonstrate cursors
POLYDG	demonstrate vector plotting
QUADER	create test image (ascending ramps in two channels)
SELCOL	route memories via SFG to video
SHOVLY	checkerboard pattern in channel
SHSPLT	SFG-splitscreen capability demonstration
SPINCX	mirror all channels on vertical centerline
SPIRSC	scroll image channels in spirals
SPLTM1	generate linear ramps in memories
TESTIM	test image
TESTPAT	generate a test pattern

```
================   Development Tools   ================================

DVPTST          define an instruction for the DVP
DVPREG          run the DVP with octal register input
-
================   Management   =====================================

CREIP5          connect VAX to DEANZA
DELIP5          disconnect VAX from DEANZA
DEADMP          dump of DeAnza registers octal
STATUS          show status of deAnza environment
SWITCH          switchboard utility
SYSINT          system initialisation
-
```

CODES FOR FUNCTIONS IMPLEMENTED IN
THE DVP OPERATIONS PROGRAM DVP

DVPCLR	1	DVPCPY	2	DVPSET	3	DVPCPL	4
DVPSHF	5	DVPSHB	6	DVPXCH	7		
DVPADD	11	DVPSUB	12	DVPMUL	13	DVPDIV	14
DVPMAX	15	DVPMIN	16	DVPCNT	17	DVPSUM	18
DVPA16	19	DVPSQR	20				
DVPADC	21	DVPSBC	22	DVPMLC	23	DVPDVC	24
DVPINC	25	DVPDEC	26	DVPAVG	27	DVPLIN	28
DVPADL	29	DVPTHR	30				
STORCH	31	LOADCH	32	SETRWC	33	SCROLL	34
PIXCHK	35	SETCUR	36	NBMAP	37	NBCNT	38
ZOOM	39	SCRLZM	40				
DVPMAR	41	DVPCLB	42	DVPMCY	43	DVPMCP	44
DVPMND	45	DVPMOR	46	DVPMEO	47	DVPMEQ	48
DVPCMP	49	DVPCME	50				
DVPABS	51	DVPLOG	52	DVPEXP	53	DVPBOO	54

TO SOFTWARE SWITCHBOARD ... 99

INPUTS REQUIRED

GENERAL PROCEDURE: FIRST PROMPT IS FOR OP-CODE
SECOND PROMPT IS FOR PARAMETERS
Z IS END

RWC MEANS REGIONAL WRITE CONTROL CODE
0 - UNCONDITIONAL
1 - REGION DEFINED BY CURSORS
2 - REGION DEFINED BY CURSORS AND
RWC BIT OF ITT4
3 - REGION DEFINED BY CURSORS AND
COMPLEMENT OF RWC BIT OF ITT4

OP-CODE	
DVPCLR (1)	clear image memory
DVPCPY (2)	copy image memory
DVPSET (3)	set memory to value
DVPCPL (4)	copy image memory via lookup-table
DVPSHF (5)	shift 16 bit
DVPSHB (6)	shift 8 bit
DVPXCH (7)	exchange two images in memory
DVPADD (11)	addition 8+8 bit
DVPSUB (12)	subtraction 8-8 bit
DVPMUL (13)	multiply 8 times 8 bit giving 16 bit result
DVPDIV (14)	divide 8 into 8 bit giving 8 bit remainder
DVPMAX (15)	maximum of two channels
DVPMIN (16)	minimum of two channels
DVPCNT (17)	get count register contents
DVPSUM (18)	sum over all pixels
DVPA16 (19)	addition 16+8 bit
DVPSQR (20)	square root of 16 bit
DVPADC (21)	addition of 8 bit constant
DVPSBC (22)	subtraction of 8 bit constant
DVPMLC (23)	multiply by 8 bit constant
DVPDVC (24)	divide by 8 bit constant
DVPINC (25)	increment image memory
DVPDEC (26)	decrement image memory
DVPAVG (27)	mean of two images
DVPLIN (28)	scaled linear combination of images
DVPADL (29)	addition 8 bit modif by ITT + 8 bit
DVPTHR (30)	threshold on image
STORCH (31)	save memory to disc file
LOADCH (32)	load memory from disc file
SETRWC (33)	set regional write control bits in ITT4
SCROLL (34)	set scroll for DVP in DIBAG coordinates
PIXCHK (35)	check pixel values in memories
SETCUR (36)	allows manipulation of cursors to fix window
NBMAP (37)	map neighbourhood in binary mask to 8 bit number
NBCNT (38)	count pixel neighbourhood
ZOOM (39)	zoom
SCRLZM (40)	scroll and zoom of specified channels
DVPMAR (41)	area of mask
DVPCLB (42)	clear bit plane
DVPMCY (43)	copy mask (bit plane)
DVPMCP (44)	complement mask
DVPMND (45)	.and. masks
DVPMOR (46)	.or. masks
DVPMEO (47)	exclusive .or. masks
DVPMEQ (48)	.equivalence. masks
DVPCMP (49)	set flag mask after comparing two images =
DVPCME (50)	set flag mask after comparing two images =
DVPABS (51)	absolute value of 7 bit signed number
DVPLOG (52)	log function on image
DVPEXP (53)	exp function on image
DVPBOO (54)	boolean operations on images

END

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DTIC